The Journal of CPRI,
Vol. 8, No. 1, March 2012 pp. 25–30

Investigation on Polarization – Depolarization Current Measurements in Insulation Systems for High Voltage Motor

Tapan M Rami* and Prasanta Kundu**

This paper presents the assessment of insulation systems for high-voltage induction motor through measurement of insulation resistance(IR), polarization index(PI) and polarization–depolarization current or charging and discharging current. It is considered that the insulation systems are having different types and conditions of insulation aging. It demonstrates that the IR and PI cannot be used individually to judge insulation dryness, and the combination of IR and polarization and depolarization current (PDC) analysis is a better technique of insulation quality assessment than the insulation resistance alone. The PDC analysis is non-destructive dielectric testing method for determining the conductivity and moisture content of insulation materials in high-voltage motors. On the basis of this analysis, it is possible to take further actions like overhauling, drying process and replacement of the winding of the motor. This paper also presents a description of PDC analysis technique with the practical and theoretical background and some results of IR, PI and PDC measurements on High-voltage motor.

1.0 INTRODUCTION

Large numbers of high-voltage motors around the world are approaching towards the end of their design life. They are very expensive to replace; however, some of these motors are still in good condition and could be used for some more years. One way to achieve this objective is to increase the time interval between maintenance outages and reduce the time of the outage. Towards this end, detecting defects at an early stage, being able to model and predict the growth of such defects and integrating maintenance to mitigate the consequent reduction in reliability are critical to ensure that the motors survive from one outage to the next with the desired reliability. Various industrial surveys show that problems initiated in the stator winding insulation are one of the leading root causes of high-voltage motors failure. It is known that up to 70 % failure of high-voltage motors results from stator insulation problems. Stator insulation aging and breakdown can cause a costly, forced outage and significant loss of revenue as well as repair/replacement costs. Therefore, prevention of such outage is major concern for both the manufacture and the end user. To this end, there has been a lot of effort towards developing reliable insulation quality assessment techniques [1–3].

While performing insulation resistance (IR) and polarization index (PI) measurements in motors with modern day insulation systems, it is often noticed that good/acceptable IR and PI values are obtained in spite of the motor winding being excessively contaminated. This is mainly due to the fact that IR and PI measurements are largely reflective of charge transport rather than charge storage mechanisms. Charge storage analysis is useful since it is possible to identify whether charge is stored in normal "traps" within insulation or within contaminants that are likely

* Manager, Essar Oil Ltd., Refinery Site, 39 KM, Jamnagar-Okha Highway, Vadinar - 361305, Gujarat, India. E-mail: Tapan.Rami@essar.com
** Department of Electrical Engineering, S V National Institute of Technology, Surat - 395 007. E-mail: pk@eed.svnit.ac.in

to be present in the insulation. The polarization and depolarization current (PDC) analysis is used to quantify and characterize charge storage mechanisms, and therefore a reliable indicator of presence of contamination [4–7].

The paper has been investigating the PDC measurement for separation of moisture and aging impact on motor insulation degradation. One case study is presented, where the testing of high-voltage motor is carried out at healthy situation, moisture and conductive contamination situation of insulation system. The test results are compared to determine the condition of insulation system of motor and to assess the healthiness of the motor.

2.0 THEORETICAL AND EXPERIEMNTAL DETAILS

2.1 Polarization Index (PI)

It is a ratio of insulation resistance at two different times, typically 10 minutes and 1 minute. The one minute reading of insulation resistance (IR) has been successfully used by maintenance engineers since long times. To detect the conduction problems and to judge the insulation dryness, PI can be used individually. This is presented later though a case study. It is well-accepted that a very bad PI values need not at all mean a high probability of insulation failure, and a very good PI may be obtained when failure is imminent [1,2,4].

2.2 Polarization and Depolarization Current (PDC)

The principle of PDC measurement is as follows. A DC voltage of 2500 V is applied to the winding/windings using a highly regulated electronic power supply with a stability of <1 v/sec. The voltage is maintained for a time period of not less than 1000 seconds. The current flowing through the insulation is monitored during this charging period. Then, the windings are discharged through a micro ammeter and discharge currents are monitored after the initial winding capacitance discharge (<5 secs), over a total time period that will not be less than the charging time period. The charging and discharging currents are plotted on a log–log scale and analyzed in the times domains [3,4].

The schematic diagram of the PDC measuring set-up is shown in Figure 1.

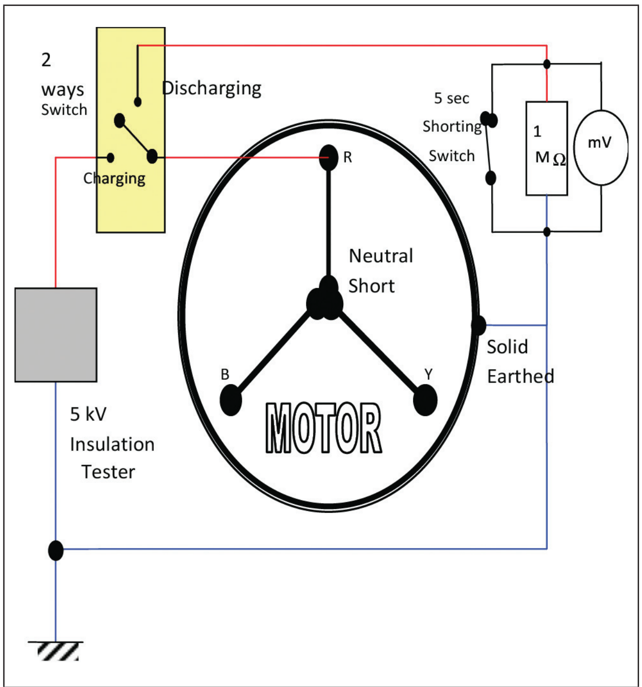

FIG. 1 PDC MEASURING SETUP

The procedure for taking readings of charging and discharging current of insulation is as follows.

(i) The setup shown in circuit diagram (Figure 1) in charging mode is made.

(ii) The capacitance between winding and earth (i.e. between each phase and other two grounded phases) is measured in both polarities.

(iii) The initial leakage current in nA is measured with multimeter connected across 1 M Ohm resistor in both polarities.

(iv) Now the winding is energized with IR Tester at 2.5 kV for 17 minutes and the IR values are noted down at regular time intervals. IR values are recorded with intervals of 5 secs for initial 30 sec, then with intervals of 10 secs for next up to 2 mins and later with intervals of 30 secs. Thus, immediately after applying the test voltage, the readings will have to be taken fast.

(v) After charging for 17 minutes, the circuit is connected in discharging mode so that the IR tester is not in circuit and motor terminals are connected to discharging circuit. However, during discharging, the 1 M ohm resistor is shorted for initial 5 sec to discharge high initial current. After 5 sec, the shorting link of 1 M ohm resistor is opened and the mV readings on multimeter connected across 1 M ohm resistor are noted.

(vi) The above procedures are repeated for each individual cases in new and healthy, moisturize and conduction condition.

For each case study in this contribution, plots of insulation resistance versus time are accompanied by the PDC analysis with the charging current and discharging current versus time are presented. These are for better understanding of the characteristics of each aging type [6–7].

3.0 RESULTS AND DISCUSSIONS

3.1 Case 1 New and Good Insulation Condition

Figures 2(a) and (b) present dielectric response results for three diagnostic parameters: IR, PI and charging and discharging currents of the motor. It is considered as good insulation because following characteristics.

(a) The shape of insulation resistance for a good and dry motor is straight and increases with time. The value of insulation resistance should be high and PI should be more than one for good and dry machine. Here, IR value is more than 10 M ohm and PI is more than 4, which shows a good result.

(b) When the insulation system is good and dry, the polarization current and depolarization current are nearly equal for about one-tenth of the charging time as shown in Figure 2. Both currents are straight in log-log scale. The magnitude of PDCA depends mostly on the capacitance and insulation condition.

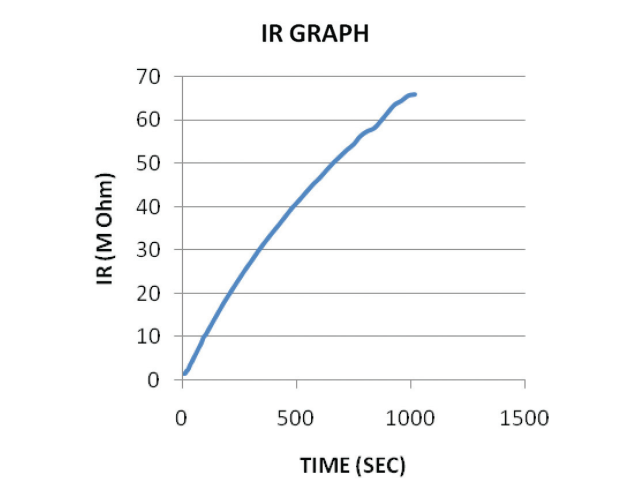

FIG. 2(A) INSULATION RESISTANCE VS TIME CHARACTERISTICS FOR CASE 1

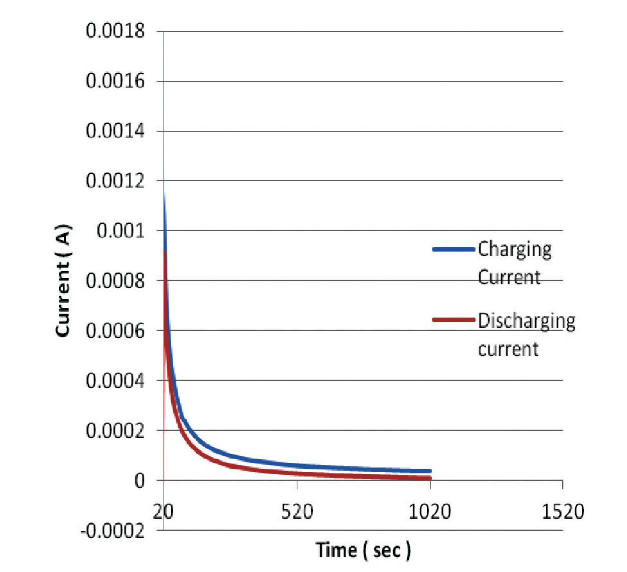

FIG. 2(B) CHARGING AND DISCHARGING CURRENT VS TIME CHARACTERISTICS FOR CASE 1

3.2 Case 2 Moisturize Insulation Condition

Moisturizing of insulation is done by steam flow inside the insulation winding. Here, moisture is mainly adsorbed in the insulation, without surface humidity, free water or other conductive contaminants (conduction).

The dielectric response results, in this case, are shown in Figures 3(a) and (b).

The value of insulation resistance is in Mega ohm range and comparable with the good insulation condition. Hence, PI and IR are not sensitive to moisture in adsorbed state. In this situation, PI cannot be used alone to judge insulation dryness.

The shape of PDC characteristics (as shown in Figure 3), is very close and similar to case 1, but it is found that the current amplitude of this stator is substantially higher, i.e. 0.0015 A in comparison to 0.0012 A.

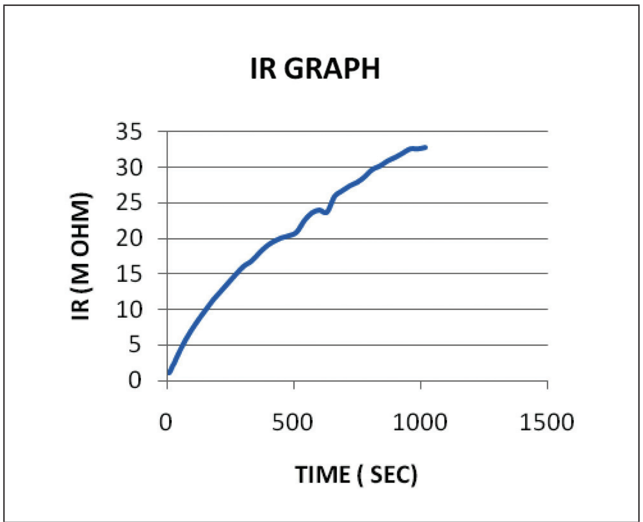

FIG. 3(A) INSULATION RESISTANCE VS TIME CHARACTERISTICS FOR CASE 2

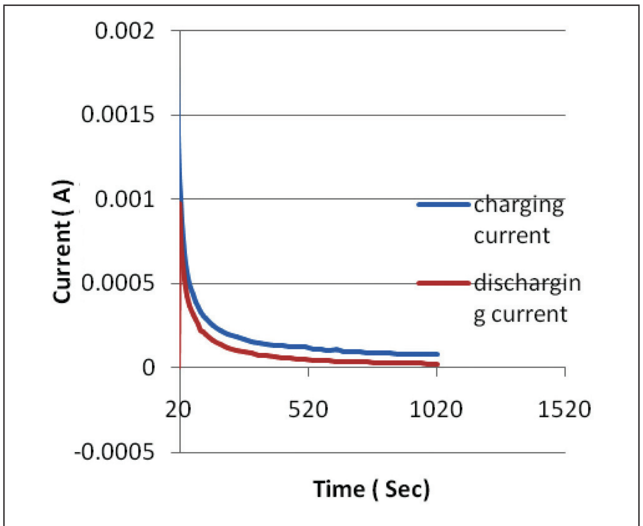

FIG. 3(B) CHARGING AND DISCHARGING CURRENT VS TIME CHARACTERISTICS FOR CASE 2

3.3 Case 3 Moisturize with Conduction of Insulation

Figures 4(a) and (b) show the dielectric response results of moisture and conductive contaminants especially carbon dust.

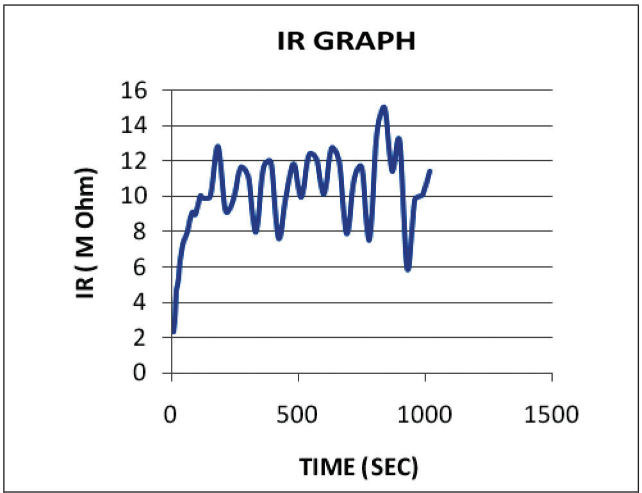

FIG. 4(A) INSULATION RESISTANCE VS TIME CHARACTERISTICS FOR CASE 3

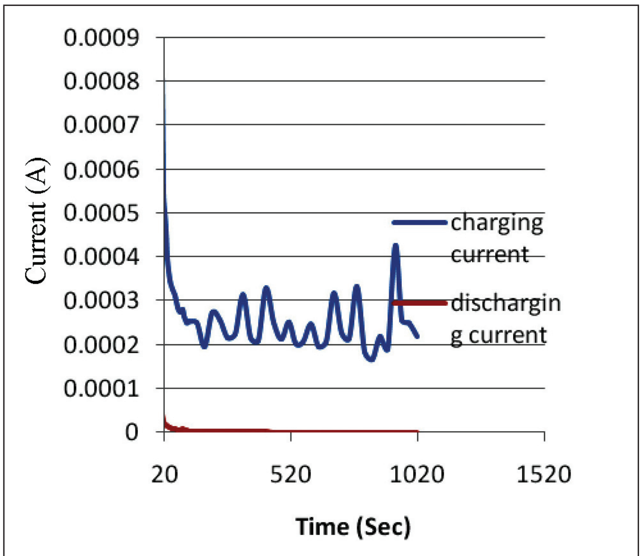

FIG. 4(B) CHARGING AND DISCHARGING CURRENT VS TIME CHARACTERISTICS FOR CASE 3

Figure 4(a) shows that there are no increase of IR values between 15 and 60s and a significant fluctuation is observed in IR values. The values of insulation resistance are low compared with the moisturize condition. This result shows that the higher value of 1 min. IR does not always mean safe for operation.

Figure 4(b) shows that the deviation of charging and discharging current. This is a very highly distorted and unusual shape of charging and discharging current, may be because of the much deteriorated insulation condition of motor. Unlike moisture in adsorbed state, surface humidity or free water or conduction problems influence the PDCA shape.

4.0 CONCLUSIONS

This Paper describes the usefulness of PDCA technique as a modern non-destructive tool for the condition assessment of high-voltage motor insulation. From the field test results, presented in this paper, it appears that both the polarization and depolarization currents are strongly influenced by the moisture contents, conductivity state of the insulation. Three diagnostic parameters, IR, PI and PDCA, are applied for interpretation of dielectric response results.

PI is sensitive to problems caused by conductive contaminants (carbon dust, surface humidity or free water). PI cannot be used alone to judge insulation dryness, since PI can still be high in case of moisture in the absorbed state if no conductive contaminants are included. Moisture in the absorbed state decreases IR without changing the nature of PDC. PDC shape can identify conductive contaminants.

In all case studies shown, PI and PDCA provide the most efficient and decisive indicator in the assessment of global problems in high-voltage motor insulation.

ACKNOWLEDGMENT

Many thanks to Essar Oil Ltd. for sparing the high-voltage motor for investigation of insulation. Authors want to also express their gratitude to SVNIT, Surat, for providing support for this research work.

REFERENCES

[1] IEEE Std.43-2000. IEEE Recommended Practice for *Testing Insulation Resistance of Rotating Machinery*, 2000.

[2] Stone G C, Boulter A, Culbert I and Dhirani H. “Electrical insulation for rotating machines”, *IEEE, Press series on Power Engineering*, *IEEE Press*, 2004.

[3] Stone G C. “Recent important changes in IEEE motor and generator winding insulation diagnostic testing standards”, *IEEE, Trans. on Industry Applications*, Vol. 41, No. 1, pp. 91–100, January-February 2005.

[4] Vicki Warren and Gereg Stone, (Iris Power Engineering). “Recent developments in diagnostic testing of stator windings”, 0883-7554/98-IEEE 1998 P16-24.

[5] Bhumiwat S A. “On site non destructive dielectric response diagnosis of rotating machines”, *IEEE, Transactions on dielectrics and Electrical Insulation,* Vol. 17, No. 5, pp. 1453–1460, October 2010.

[6] Bhumiwat S A. “Insulation resistance and polarization of rotating machines”, Electrical Insulation Conference, Annapolis, Maryland. 978-1-4577-0279-2/11-IEEEE. pp. 249–253, 2011.

[7] Bhmiwat S. “Application of polarization depolarization current (PDC) technique on fault and trouble analysis of stator insulation”, in CIGRE SC A1 and D1 Joint Colloquium Gyeongju, Korea, pp. 79–87, October 24, 2007.